Name _____ AP Chemistry

Classification of Chemical Reactions

Introduction

There are over 100 known elements and millions of known compounds. Throughout history, chemists have sought to organize the wealth of data and observations that have been recorded for these substances. In this experiment you will perform examples of each of the following reaction types: precipitation, acid-base, and oxidation-reduction.

PART I: PRECIPITATION REACTIONS

Certain substances are not very soluble in water. Frequently, such substances are generated in situ in a reaction vessel. For example, silver chloride is not soluble in water. If an aqueous solution of silver nitrate (soluble) is mixed with an aqueous solution of sodium chloride (soluble), the combination of silver ions from one solution and chloride from the other solution generates silver chloride, which then forms a precipitate that settles to the bottom of the container. The solution that remains above the precipitate of silver chloride effectively becomes a solution of sodium nitrate. Silver ions and sodium ions have switched partners, ending up in a compound with the negative ion that originally came from the opposite substance:

$$AgNO_3\ (aq) + NaCl\ (aq) \rightarrow AgCl\ (s) + NaNO_3$$

The silver ion and sodium ion have replaced each other in this process; this sort of reaction is sometimes referred as a displacement reaction.

PART II: ACID-BASE REACTIONS

There are many theories and definitions that attempt to explain what constitutes an acid or a base. An early but still useful theory, developed by Arrhenius in the later 1800s, defines an acid as a substance that produces hydrogen ions (H^+) when dissolved in water. A base, according to Arrhenius, is a species that produces hydroxide ions (OH^-) when dissolved in water. For example, hydrogen chloride is an acid in the Arrhenius theory, because hydrogen chloride ionizes when dissolved in water and releases hydrogen ions:

$$HCl \rightarrow H^+ + Cl^-$$

The most important reaction of acids and bases is neutralization. The hydrogen ion from an aqueous acid combines with the hydroxide ion from an aqueous base, producing water. For example:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

The net reaction for the above reaction is typical of the reaction between acids and bases in aqueous solution:

$$H^+ + OH^- \rightarrow H_2O$$

PART III: OXIDATION-REDUCTION REACTIONS

A large and important class of chemical reactions can be classified as oxidation-reduction (or redox) processes. Oxidation-reduction processes involve the transfer of electron from one species to another. For example, in the reaction

$$Zn\ (s) + CuSO_4\ (aq) \rightarrow ZnSO_4\ (aq) + Cu\ (s)$$

Zn (s) represents uncharged elemental zinc atoms, whereas in $ZnSO_4$ (aq), zinc exists in solution as Zn^{2+} ions. Each zinc atom has effectively lost two electrons in the process and is said to have been oxidized:

$$Zn\ (s) \rightarrow Zn^{2+} + 2\ e^- \qquad \textit{oxidation}$$

Oxidation is defined as a loss of electrons by an atom or ion, or better, as a transfer from one species to another. Similarly, in the preceding reaction, each Cu^{2+} ion in solution has gained two electrons, becoming uncharged elemental copper atoms

$$Cu^{2+}\ (aq) + 2\ e^- \rightarrow Cu\ (s) \qquad \textit{reduction}$$

Copper ions are said to have been reduced in the process. Reduction is defined as a gain of electrons by a species, or better, as transfer of electrons to one species from another.

Prelab Questions

1) What observations might you make that suggest that a chemical reaction has occurred?
2) Write the balanced molecular equation, predicting the products of each of the following reactions:
   (a) $AgNO_3\ (aq) + KCl\ (aq) \rightarrow$
   (b) $Pb(C_2H_3O_2)_2\ (aq) + K_2SO_4\ (aq) \rightarrow$
   (c) $BaCl_2\ (aq) + H_2SO_4\ (aq) \rightarrow$
   (d) $BaCl_2\ (aq) + K_2CrO_4\ (aq) \rightarrow$
   (e) $BaCl_2\ (aq) + (NH_4)_2CO_3\ (aq) \rightarrow$
   (f) $HCl\ (aq) + NaOH\ (aq) \rightarrow$
   (g) $CH_3COOH\ (aq) + NaOH\ (aq) \rightarrow$
   (h) $HCl\ (aq) + Na_2CO_3\ (s) \rightarrow$
   (i) $Zn\ (s) + Pb(C_2H_3O_2)_2\ (aq) \rightarrow$
   (j) $Cu\ (s) + AgNO_3\ (aq) \rightarrow$
   (k) $H_2O_2\ (l) \rightarrow$
   (l) $Zn\ (s) + CuSO_4\ (aq) \rightarrow$

Procedure

A. PRECIPITATION REACTIONS
   1) Combine 5 drops of each of the 0.1 M aqueous solutions below together in a well plate and make any observations:
      (a) $AgNO_3$ (aq) & KCl (aq)
      (b) $Pb(C_2H_3O_2)_2$ (aq) & K_2SO_4 (aq)
      (c) $BaCl_2$ (aq) & H_2SO_4 (aq)
   2) Combine 5 drops of 0.1 M $Pb(C_2H_3O_2)_2$ and 6 M HCl. Make any observations.
   3) Combine 5 drops of 0.1 M $BaCl_2$ and 1 M K_2CrO_4. Make any observations.
   4) Combine 5 drops of 0.1 M $BaCl_2$ and 3 M $(NH_4)_2CO_3$. Make any observations.

B. ACID-BASE REACTIONS
   1) Obtain 2.0 mL of 0.1 M HCl and add 1 drop of universal indicator. Record the color of the solution and the pH.
   2) Add 5 drops of 0.1 M NaOH and record the color and pH of the solution.
   3) Continue until pH of the solution is above 10.
   4) Repeat steps 1-3 with 2 mL of 0.1 M CH_3COOH.
   5) Obtain a small amount of solid Na_2CO_3 in a test tube and add several drops of 6 M HCl.
   6) Record your observations, including the odor and color of the gas that forms.

C. OXIDATION-REDUCTION REACTIONS
   1) Obtain 20 mL of 3% hydrogen peroxide in a large test tube. Also obtain a wooden splint and a crystal of $KMnO_4$.
   2) Light the wooden splint and then blow out the flame so the splint is only glowing.
   3) Place the $KMnO_4$ crystal into the test tube of hydrogen peroxide. Insert the wooden splint into the test tube, careful not to get it wet. Record any observations.
      - If oxygen is present, then the glowing splint will burst into flames.
   4) Obtain 2 strips of zinc metal. Place one in each of the following solutions:
      (a) 2 mL of 0.5 M $CuSO_4$
      (b) 2 mL of 1 M $Pb(C_2H_3O_2)_2$
   5) Allow the solutions to sit for 15 minutes and record any observations.
   6) Obtain a piece of Cu wire and place in 2 mL of 0.1 M $AgNO_3$.
   7) Allow the solution to sit for 15-20 minutes and record any observations.

Data/Results

Create a table for each part for your observations.

Postlab Questions

1) In part A, for each reaction, what is the solid formed?

2) In part B, considering that 20 drops approximately equals one milliliter, what volume did it take to neutralize 0.1 M HCl and 0.1 M CH_3COOH? Is there any difference? If so, why?
3) Write the net ionic equation for each of the following reaction:
   (a) $AgNO_3$ (aq) + KCl (aq) →
   (b) $Pb(C_2H_3O_2)_2$ (aq) + K_2SO_4 (aq) →
   (c) $BaCl_2$ (aq) + H_2SO_4 (aq) →
   (d) $BaCl_2$ (aq) + K_2CrO_4 (aq) →
   (e) $BaCl_2$ (aq) + $(NH_4)_2CO_3$ (aq) →
   (f) HCl (aq) + NaOH (aq) →
   (g) CH_3COOH (aq) + NaOH (aq) →
   (h) HCl (aq) + Na_2CO_3 (s) →
   (i) Zn (s) + $Pb(C_2H_3O_2)_2$ (aq) →
   (j) Cu (s) + $AgNO_3$ (aq) →
   (k) H_2O_2 (l) →
   (l) Zn (s) + $CuSO_4$ (aq) →
4) For all the reactions in part C, identify the reducing agent and oxidizing agent in each reaction.

*Adapted from "Classification of Chemical Reactions"—Hall, J.F.; *Experimental Chemistry (7th Edition)*, 2007, p. 245-260. & "Chemical Reactions"—Nelson, J.H.; Kemp, K.C.; *Chemistry: The Central Science (Laboratory Experiments)*, 2006, p.37-45.